EMCal Optical Sensors and Readout Electronics
WBS 1.07/1.08

E.J. Mannel

EMCal Internal Review

20-Aug-2015

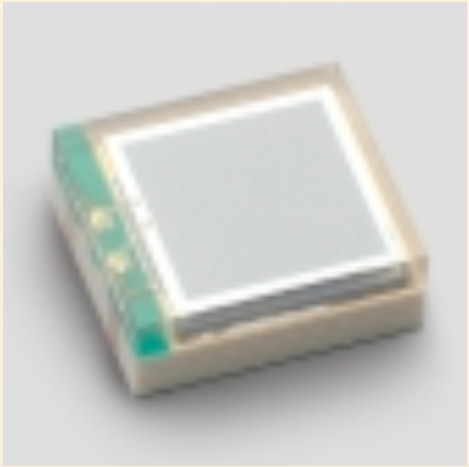
OPTICAL SENSOR

EMCal Electronics Design Concept

- Minimize custom ASICs -> off the self components
- Same optical sensor for EMCal and HCal
- Similar readout for both EMCal and HCal
  - Continuous digitization of wave forms
  - Trigger primitives for Level-1 trigger
  - High DAQ rate, ~15KHz
- Minimize On-Detector power/heat load
- Use PHENIX DAQ
  - DCM-II
  - Event Builder
  - Data Logging
  - Monitoring
- Common biasing and low voltage systems

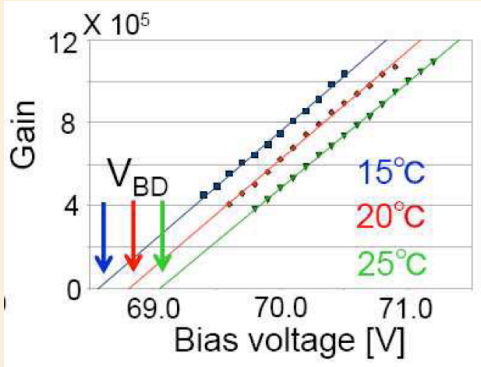
Optical Sensors Reference Design

- Silicon Photomultiplier, SiPM or MPPC
- High gain, ~10^5
- Immune to magnetic fields
- Relatively inexpensive, ~$10 in large quantities
- Reference device: Hamamatsu S12572
  - 15 μm^2 pixel size
  - 40K microcells
  - ~25% Photon Detection Efficiency (PDE)
- Potential concerns
  - Temperature dependence
  - Radiation effects

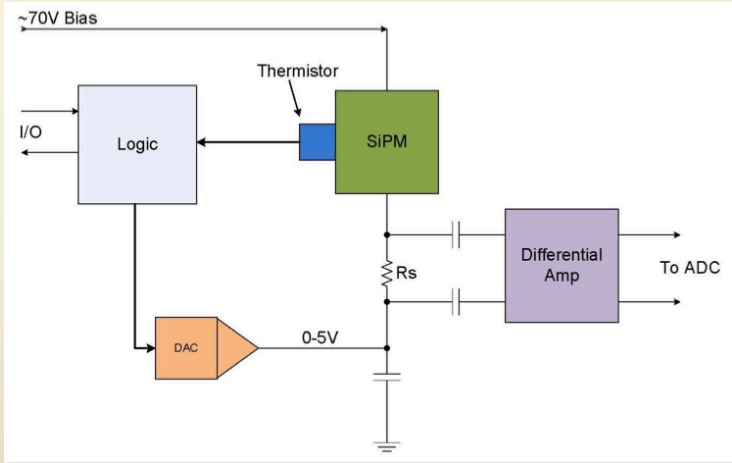


Temperature Dependence

- SiPM gain is set by the overvoltage applied to the device:
  - $V_{op} = V_{br} + V_{ov}$
- Temperature dependence:
  - ~10 %/^{0}C
- Local thermistor to monitor temperature
- Positive feedback loop will be used to adjust the voltage to compensate for temperature fluctuations

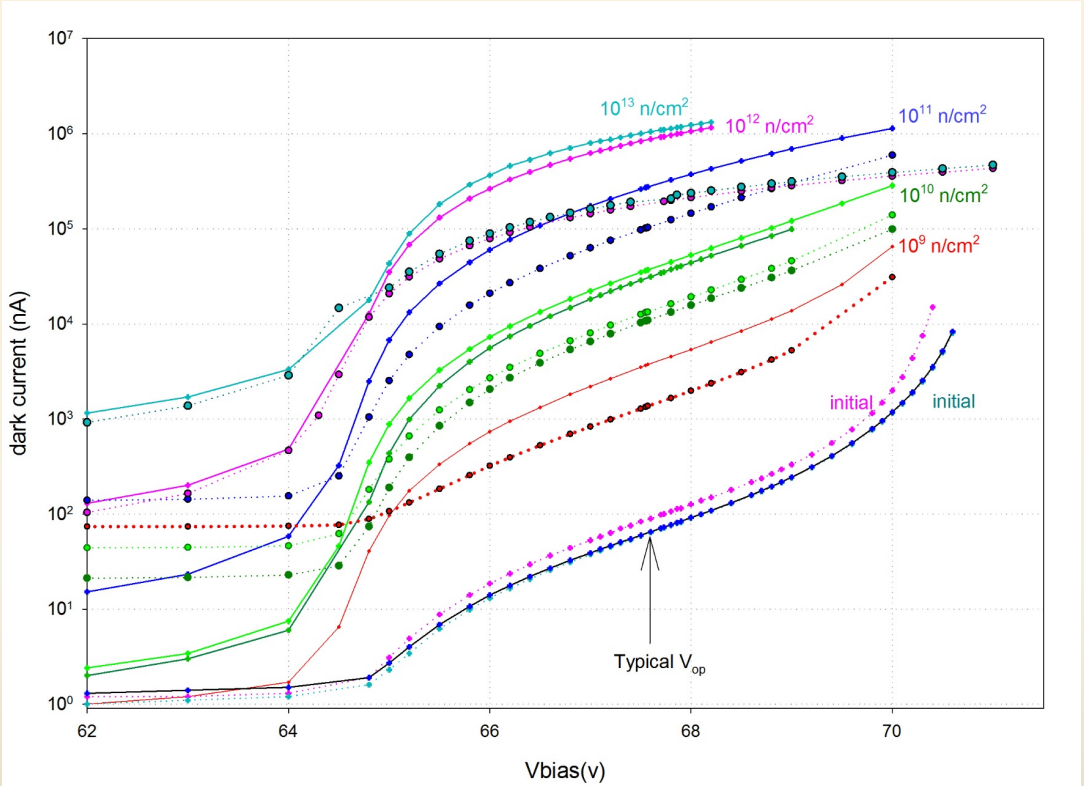


Minamino, Akihiro at al.
"T2K experiment: Neutrino Detectors"



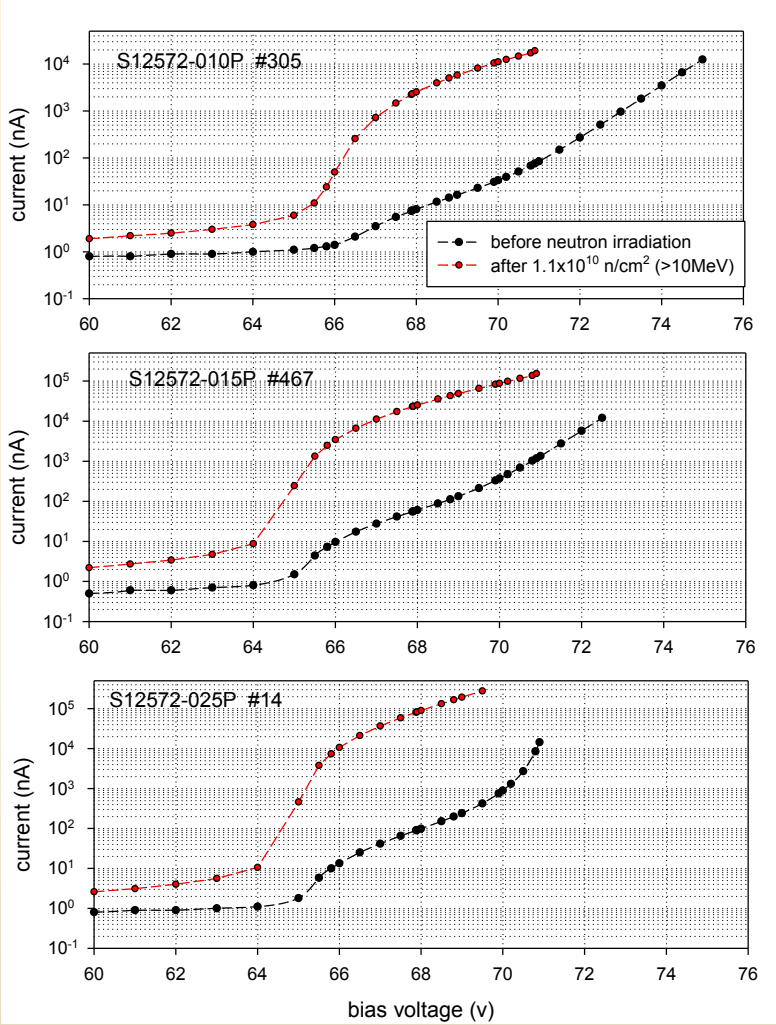
Radiation Effect

- Displacement damage due to neutrons- Increased leakage current
- Study the effects of neutron damage at:
  - LANSCE (LANL)
  - LENS (Indiana Univ.)
  - PHENIX IR
  - BNL Instrumentation



Dark Current vs Bias Voltage

- Measurements taken at LANSCE (Dec 2014)
- 3 pixel sizes: 10μm, 15μm and 25μm
- Measure dark current before and after irradiation
- No correction for voltage drop in current limiting resistor.

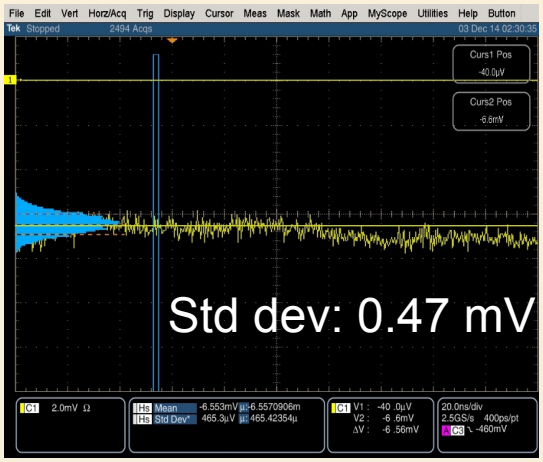


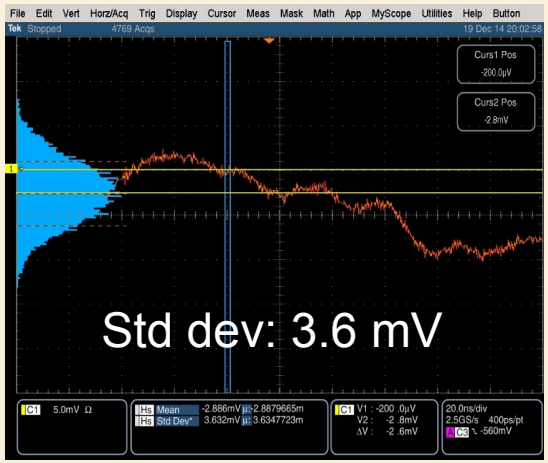
MPPCs - sPHENIX preamp /LED pulser peak and pedestal measured after irradiation (7.2×10^{10} / cm^2).

Before irradiation

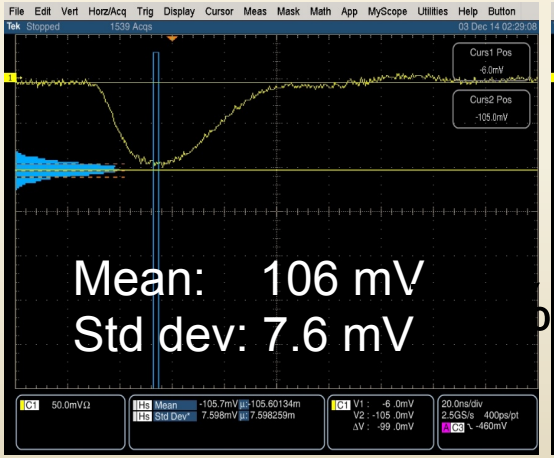
After irradiation

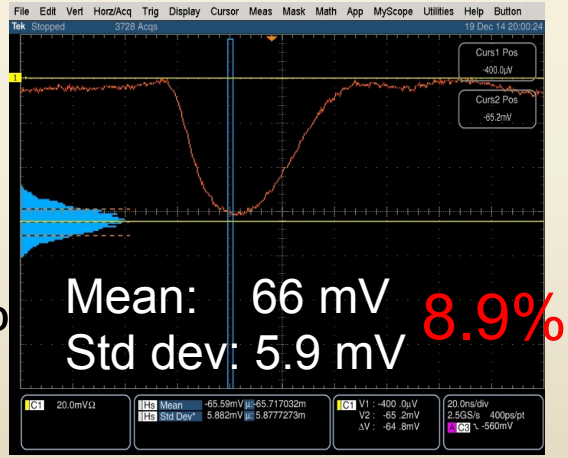
pedestal





Peak



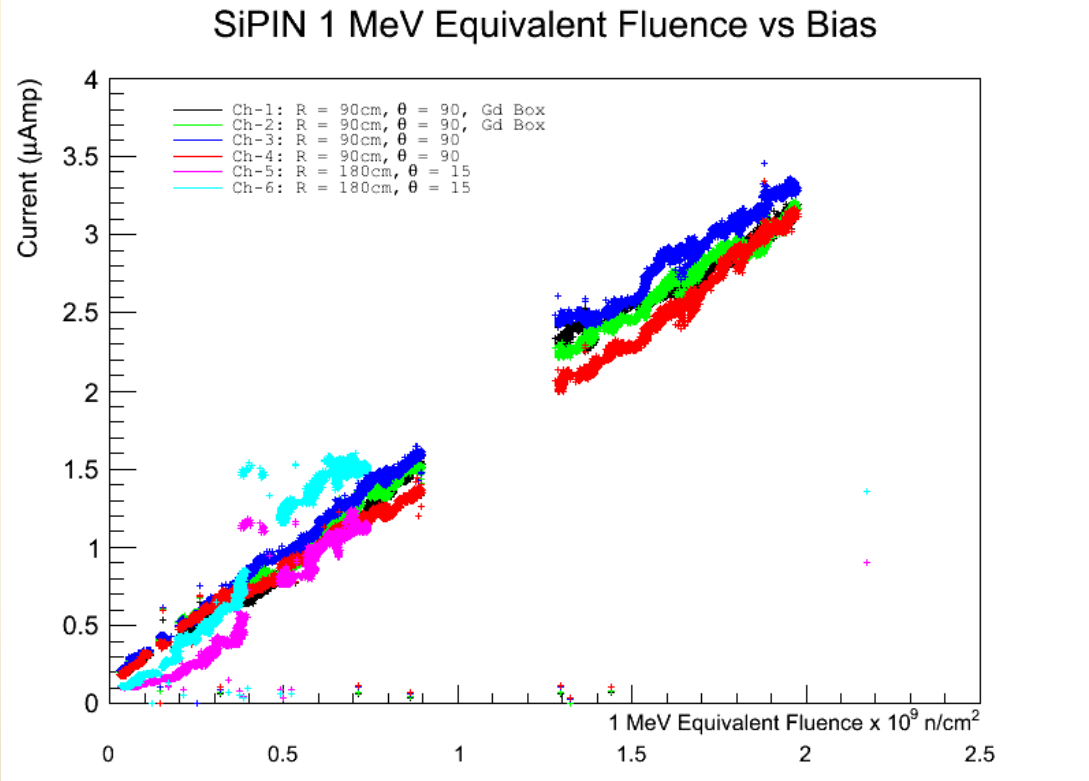


8.9%

neutron irradiation at LANSCE

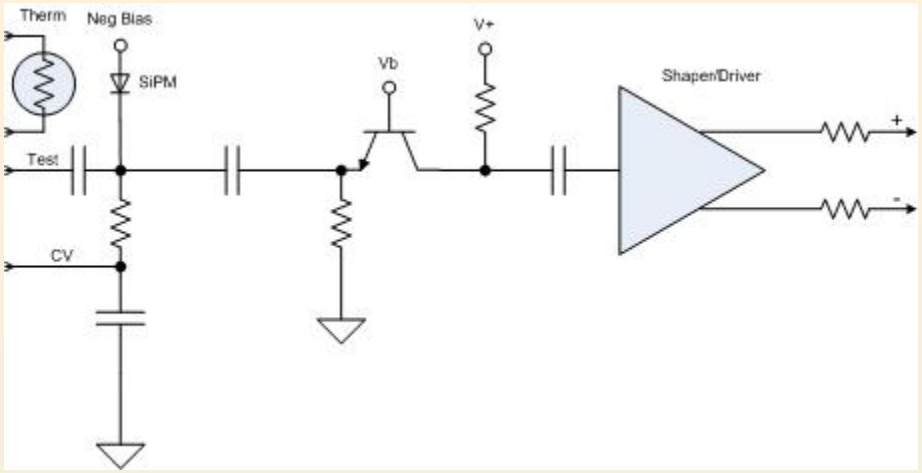
PHENIX IR Measurements

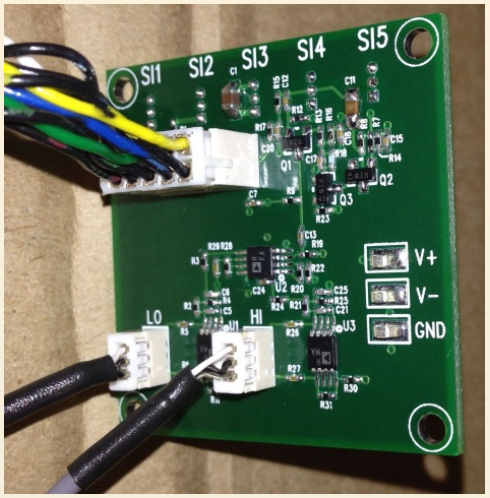
- 6 SiPMs (25μm^2 devices)
- Devices located at 2 locations:
  - 90cm from IP at $\Theta = 90^0$
  - 180cm from IP at $\Theta = 15^0$
- Measure current at fixed voltage May/June 2015
- Use CERN RadFETs to measure 1MeV neutron equivalent fluence



FRONT ELECTRONICS

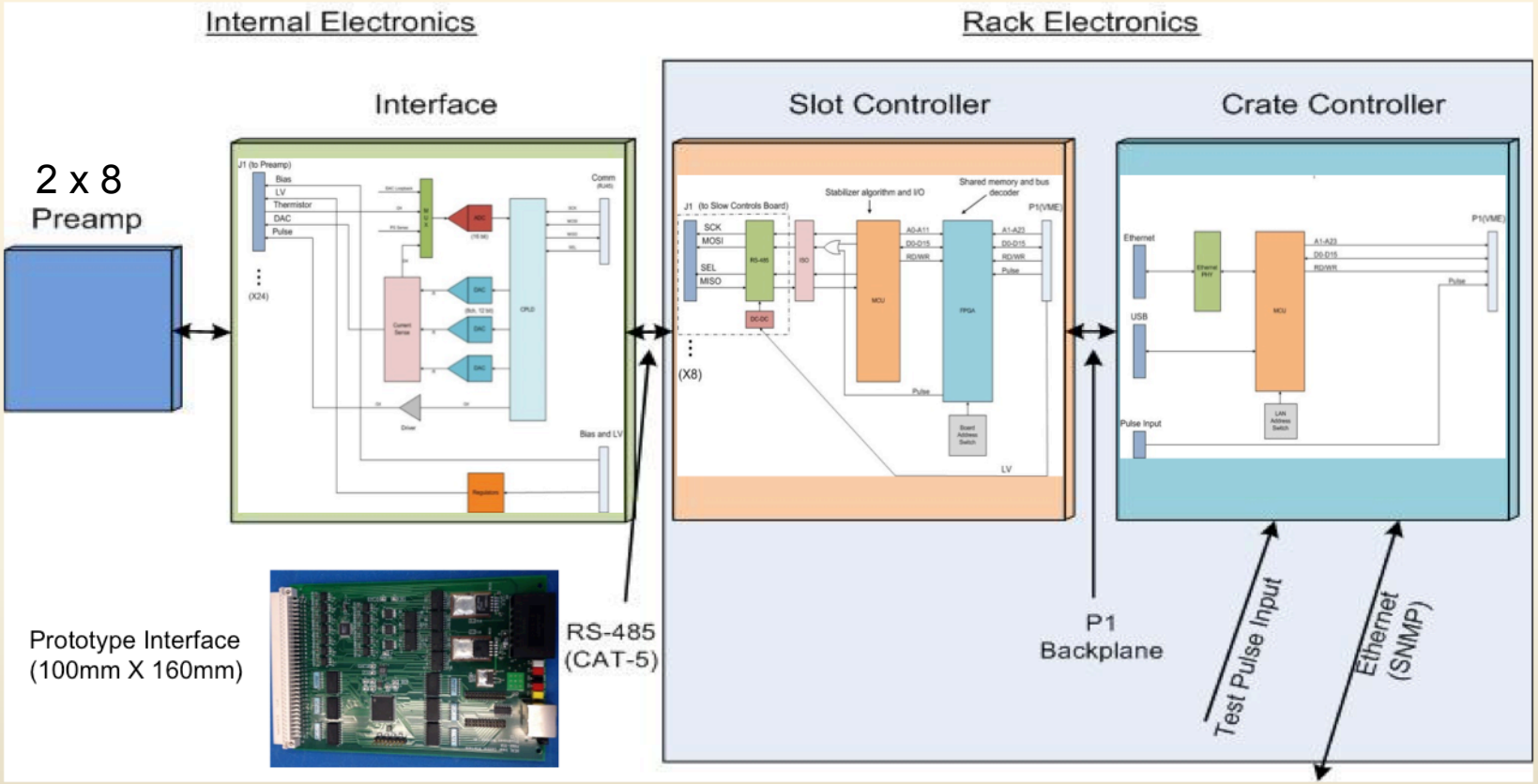
Preamp Circuit





- *Local thermistor for temp monitoring.*
- *Control voltage input for trimming bias +/- 2.5V.*
- *Charge injector for signal test.*
- *Differential multiple-feedback filter/driver with 30nS peaking time for 65MHz ADC sampling.*
- *P_D:*
  - *CBA ~ 80mW*
  - *Buffer/Amp ~ 50mW*
  - *Shaper/ Driver ~ 120mW*
  - *P_{tot} ~ 250mW*

Front End Electronics Overview

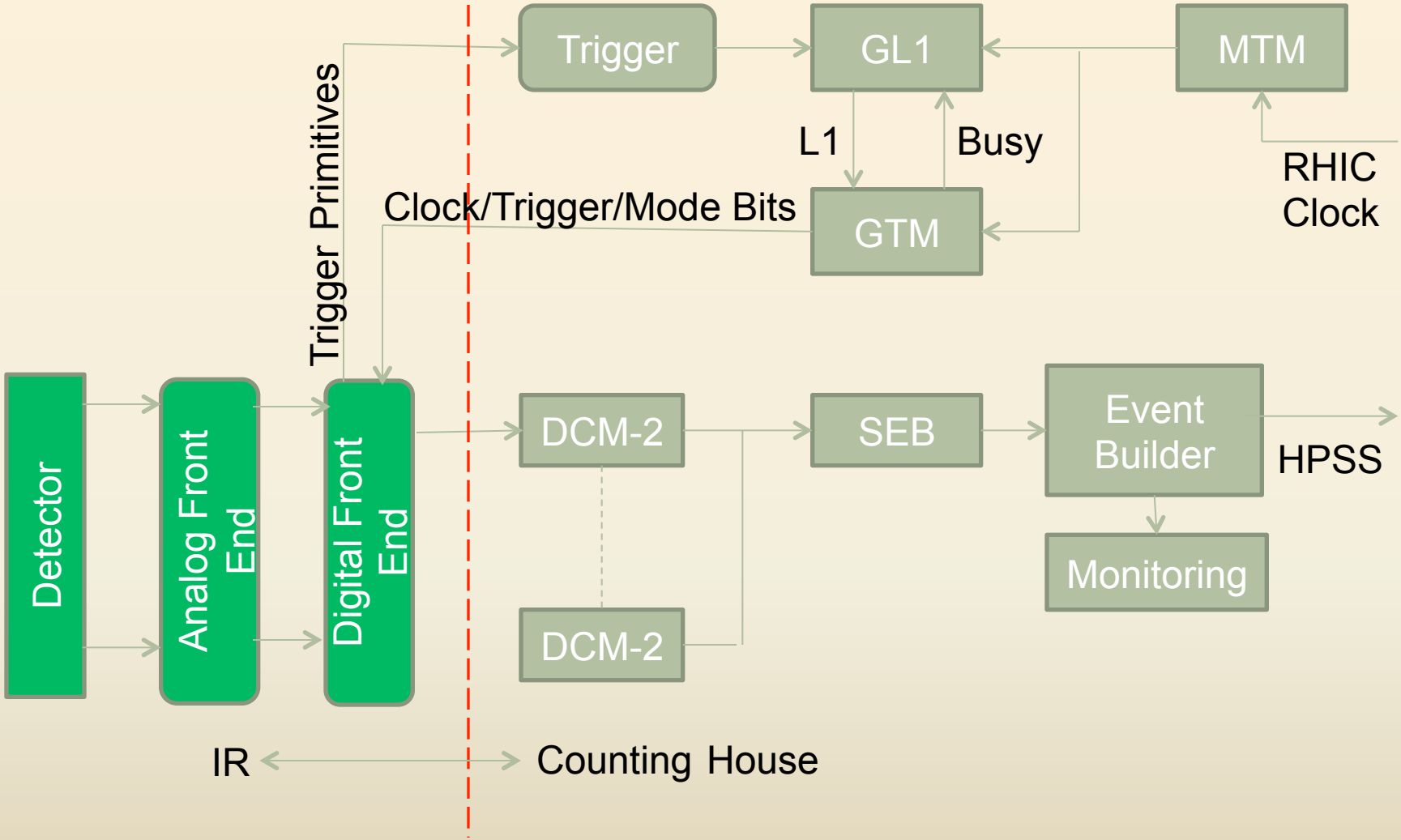


DIGITIZERS, TRIGGER AND DAQ

sPHENIX DAQ Concept

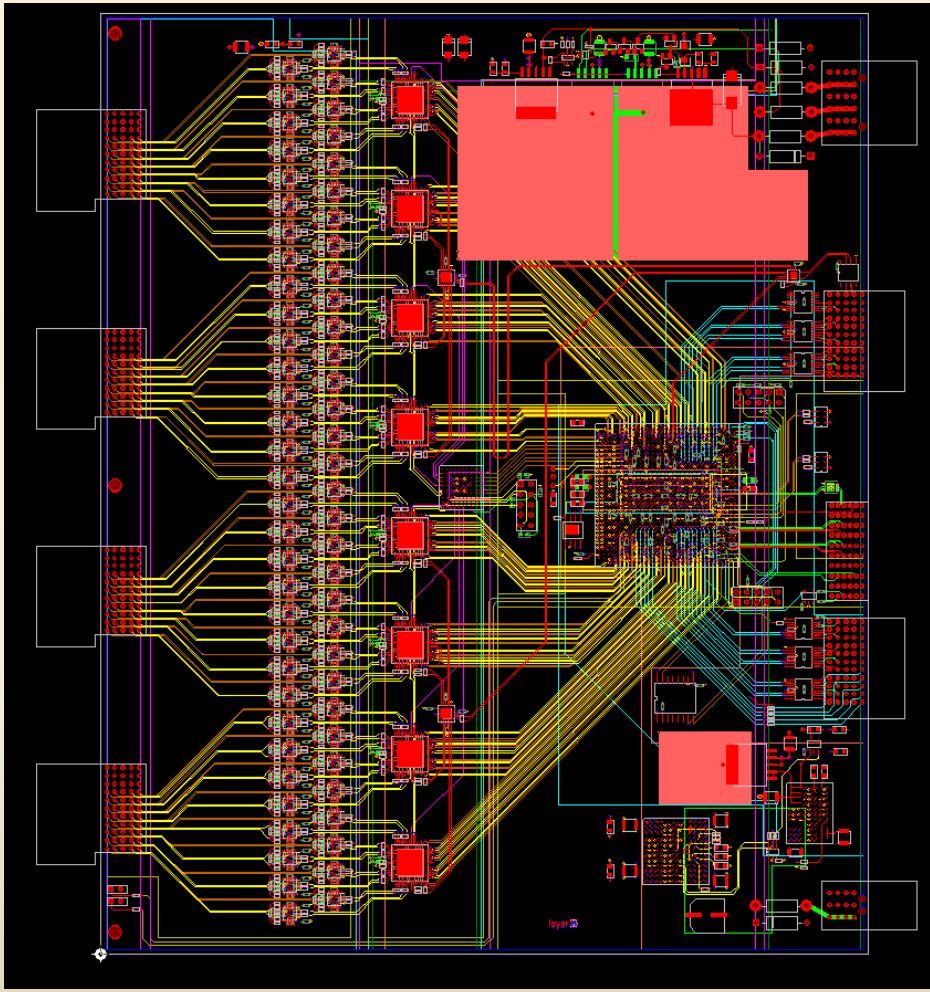
- Waveform digitization
  - Located near detector
  - 65MHz digitization rate
  - 14 Bit ADC
  - Form local trigger primitives for Level-1 trigger
  - Identical for EMCal and HCal.
- Take advantage of PHENIX hardware
  - DCM-IIs: High speed readout, ~15KHz
  - PHENIX Event Builder
  - PHENIX Timing System (MTM/GTM/GL1)

DAQ Overview

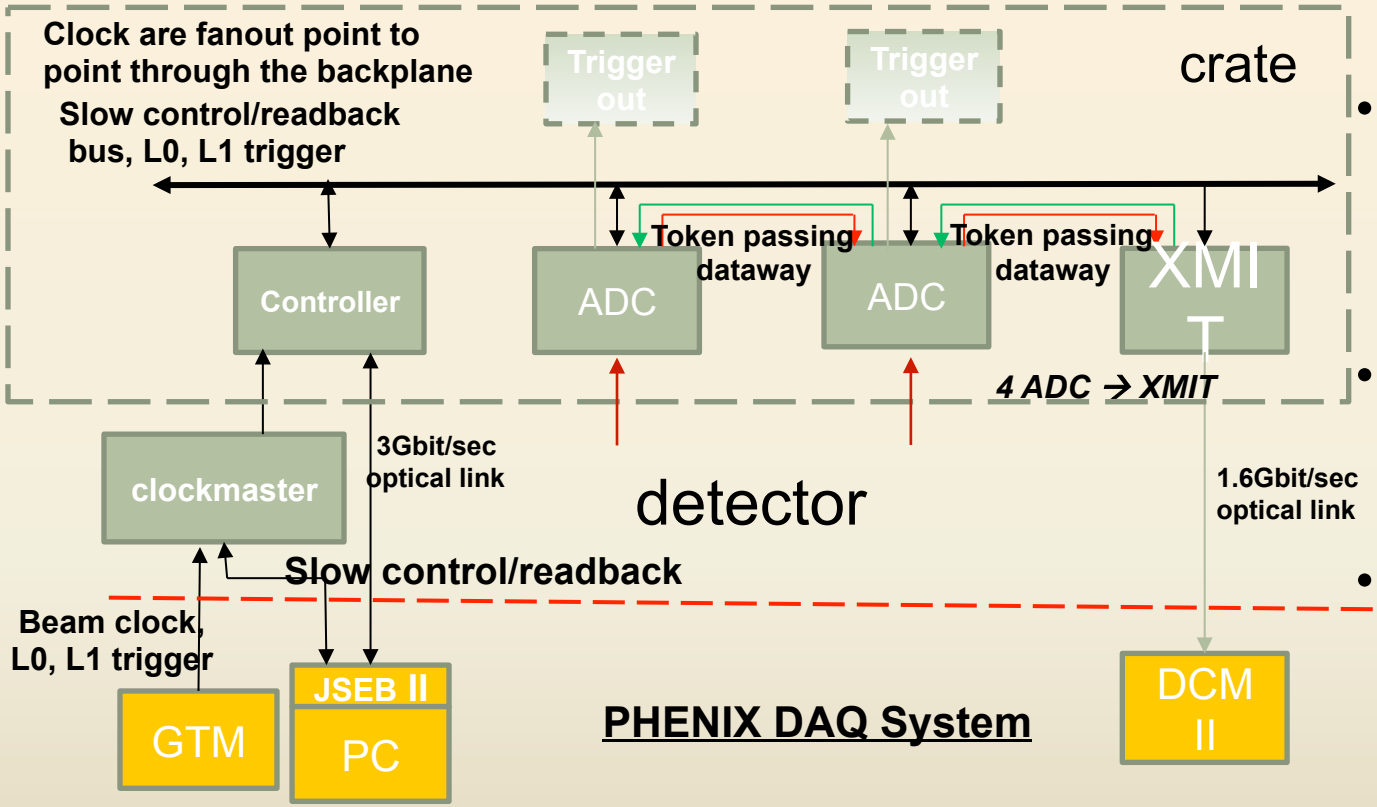


DIgitizer System

- Based on PHENIX HBD design
- 14 Bit ADC @ 65 MHz
- 64 channels per board
- Trigger Primitives based on 2x2 tower geometry
- First R&D prototypes are in fab with testing fall of 2015
- Should be available for 2016 beam test

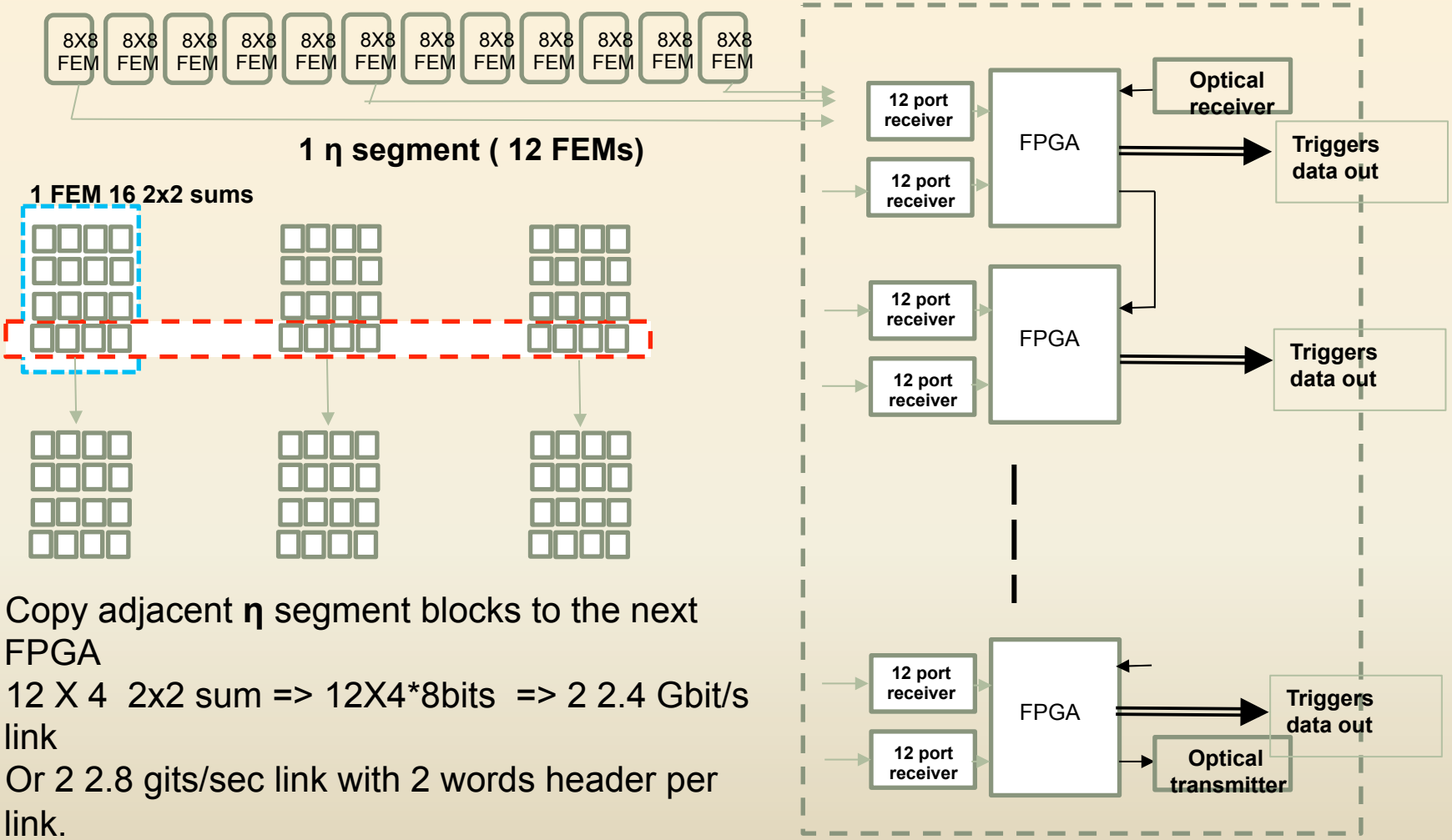


sPHENIX Digitizer System



- Crate based system
- Differential signals from on detector eletronics
- Generate L1 Trigger primitives
- Send digitized data out when L1 request received

EMCal Trigger



- Copy adjacent **η** segment blocks to the next FPGA
- 12 X 4 2x2 sum => 12X4*8bits => 2 2.4 Gbit/s link
- Or 2 2.8 gits/sec link with 2 words header per link.

Conclusions

Conclusions II

- The electronics (WBS 1.7) had internal review in March 2017 and recommendations are being addressed
- Reference sensor is the SiPM
  - Temperature dependence is well understood
  - Radiation effects are being studied
- R&D work is in progress to design and test a common base amplifier for the upcoming beam test.
- R&D work is in progress for the next generation digitizers
  - 65MHz sampling rate
  - 14 bit ADC
  - Digital pipeline
  - Trigger Primitives
- Reference design for trigger system is being developed based on 2x2 tower sums